

## VIII. Electronics Parts Engineering

### ENGINEERING MECHANICS DIVISION

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#### A. Effects of Nuclear Radiation on Electronic Parts, E. T. Klippenstein

Deep space missions possibly requiring nuclear devices for electrical power and propulsion systems have been considered at JPL. In exploring the use of nuclear devices, a matter of concern is the shielding necessary for protection of the electronics.

A two-phase program was initiated in 1962 to study the effects of nuclear radiation as part of the environment of space. The first phase consisted of reviewing the literature available and formulating an experimental program designed to provide the required information. The second phase consisted of performing the test program and reporting the analysis of the results. The total program was completed in 1966. This article will describe the program briefly, and present a summary of observations based on an engineering analysis of the test results.

The total program consisted of exposing electronic parts in seven combinations of environmental conditions (Table 1) with and without a nominal electrical stress. The radiation exposure time was 10,000 hr. The parts included in the program represented a cross section of parts typically found in spacecraft fabricated during

Table 1. Environmental conditions

Group	Temperature, °C	Pressure, torr	Power	Radiation	Time, hr
I	100	Ambient atmosphere	On	None	10,000
II	100	$10^{-5}$	On	None	10,000
III	100	$10^{-5}$	On	a	10,000
IV	100	$10^{-5}$	On	b	10,000
V	50	$10^{-5}$	On	a	10,000
VI	100	$10^{-5}$	Off	a	10,000
VII	100	Ambient atmosphere	Off	None	10,000

a  $10^6$  ncm<sup>-2</sup> hr<sup>-1</sup>,  $10^5$  rad gamma hr<sup>-1</sup> exposure for 10,000 hr.  
b  $10^{11}$  ncm<sup>-2</sup> hr<sup>-1</sup>,  $10^5$  rad (carbon) gamma hr<sup>-1</sup> exposure for 100 hr followed by 10,000 hr without radiation.

1962-1965. Included were capacitors, diodes, transistors, resistors, relays, switches and other parts representing 33 different part types, or a total of 3,418 individual piece parts (Table 2).

The total radiation exposure was approximately  $10^{11}$  ncm<sup>-2</sup> ( $E > 0.1$  mev) concurrent with  $10^7$  rad (carbon)

Table 2. Test specimens

Part	Type	Number
Capacitors	Metallized paper (P323ZN105K Aerovox)	120
	Metallized paper-mylar (118P10592S2 Sprague)	100
	Mylar (683G10592W2 Good-All)	140
	Tantalum foil (15K106AA6 G.E.)	120
	Tantalum wet slug (HP56C50D1 Fansteel)	100
Diodes	Silicon, switching (FD1184 Fairchild)	140
	Silicon, switching (FD643 Fairchild)	100
	Silicon, switching (1N916 Texas Instruments)	100
	Silicon controlled switch (3N58 General Electric)	140
	Power rectifier (1N2063 International Rectifier)	24
	Zener (1N822 Hoffman)	140
	Zener (PS4653 Pacific Semiconductors)	100
Resistors	Carbon film (CG-104 Texas Instruments)	120
	Metal-oxide-film (C-07-104 Corning Glass)	140
	Carbon composition (CB-1045 Allen Bradley)	120
	Potentiometer, conductive plastic (78PSH-128-16 NEI)	140
Transistors	Silicon NPN planar (2N911 Fairchild)	100
	Silicon NPN planar, epitaxial (2N914 Fairchild)	140
	Silicon NPN planar (2N915 Fairchild)	140
	Silicon PNP medium power (2N1132 Texas Instruments)	140
	Silicon NPN planar, epitaxial (2N2297 Fairchild)	100
	Silicon NPN planar (2N930 Fairchild)	100
	Silicon NPN power (2N1050 Texas Instruments)	140
	Silicon PNP planar epitaxial (2N2412 Texas Instruments)	100
	Silicon PNP alloy (2N861 Philco)	140
Relays	DPDT, dual coil (32RJD90GD-GSP Sigma)	100
Switches	SPDT (1HM1 Minneapolis-Honeywell)	100
Transformers	Interstage (SP-13 [TF5RX13ZZ] Triad)	100
Connectors	DEM-9P-NM-10 (Cinch)	30
	DEM-9S-NM-10 (Cinch)	30
	PT06A-8-4P (Bendix)	30
	PT00A-8-4S (Bendix)	30
Miscellaneous	Photomultiplier tube (7817, CBS)	24
	Fiber optic disc (Mosaic Fabrications, Inc.)	10
	Cadmium sulfide cells (CL-605, Clairex)	20

gamma.<sup>1</sup> The study was performed at the pool-type research reactor at the Battelle Memorial Institute, Columbus, Ohio.

Based on an analysis of the experimental results, some general observations regarding the nuclear radiation conditions of this test program are summarized as follows:

- (1) Transistors in general experienced permanent radiation damage. The effects observed were current gain decrease and saturation voltage increase with only a small percentage of recovery after radiation turn off. The amount of damage was appreciable in the medium power and power transistors. A 75% degradation of current gain was observed. However, for the fast switching types of transistors the amount of degradation was less severe and probably not significant.
- (2) Capacitors, diodes, resistors, relays, switches, transformers and connectors were apparently not affected by the amount of radiation exposure of this program.
- (3) The  $10^{11}$  ncm<sup>-2</sup> environment was applied to several groups of parts over 10,000 hr, while another group was subjected to this level of radiation over a 100-hr period followed by the 10,000-hr life test. The data showed that the radiation effect was essentially the same whether applied in a 100-hr period or a 10,000-hr period. For the group which was exposed to 100-hr radiation followed by the 10,000-hr life test, there appeared to be a small annealing effect.

In addition to the nuclear radiation testing, a small number of parts having light sensitivity measurements were tested for shorter periods of time in only a gamma radiation environment of  $10^4$  rad/hr. Based on the analysis of the data, the following was observed regarding the gamma radiation environment:

- (1) The cadmium sulfide cells decreased in cell resistance to about 50% at dim illumination and 10% at bright illumination. They were considered functional, however, at the end of the test.
- (2) Dark current increased in the photomultiplier tubes. (Testing was discontinued because dark current was nearly equal to light current after 100 hr of test.)
- (3) Transmittance decreased in the fiber optic discs to less than 1.0% of the initial value for the shorter

<sup>1</sup>ncm<sup>-2</sup> = neutrons cm<sup>-2</sup>.

wave lengths. (Testing was discontinued after 200 hr because of early degradation.)

This test program also provided information about reliability and the effects of vacuum, temperature, and

power. Very briefly stated, the reliability of parts varied and the results in this area were comparable with other JPL qualification tests. There were no apparent effects caused by vacuum. Temperature and power, however, caused significant degradation in some part types.